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EXPERIMENTAL BASED APPROACH OF BIT ERROR RATE MEASUREMENT IN 802.11 WIRELESS NETWORKS

One of the main features of wireless networks is that they are used as transmission medium of radio channels that are affected by a lot of interference. In some cases it leads to a high bit error rate (BER) level in the channel which significantly reduces its throughput.

In the article the analysis of approaches and appropriate methods for BER calculation in a wireless channel is conducted. It is shown that the methods that are used for BER measurement do not allow to calculate BER value with sufficient accuracy. An experimental based approach and appropriate model oriented method of BER calculation is offered. BER calculation is performed using a mathematical model of wireless channel throughput. As a mathematical model a modified model of wireless channel with retransmissions is used. As a basic metric for BER level calculation an experimentally measured throughput of wireless channel is used. For throughput measurement in wireless channel open source traffic generator is used. Experimental assess of method accuracy is conducted. The analysis of method accuracy shows that the proposed method allows with a high accuracy to calculate the average value of wireless channel BER level.

Keywords: *802.11 wireless networks, bit error rate calculation, model oriented method, traffic generator, wireless channel throughput.*

The problem urgency. Wireless networks of IEEE 802.11 standard are widely used in various distributed information systems. Designing and reengineering of modern networks is performed in accordance with the requirements of QoS. The goal of QoS is to provide guarantees on the ability of a network to deliver predictable results. One of the main elements of network performance within the scope of QoS is throughput of networks channels.

One of the main features of wireless networks is that they use as a transmission medium radio channels that are affected by a lot of interference. In some cases it leads to a high bit error rate (BER) level in the channel (so called error-prone channels) and, as a result, to significant reduction of its throughput. This problem is especially important for wireless local networks (WLANs) with a closed office environment structure (no direct line of sight between the AP and the stations with many obstructions between them) [1].

As it has been shown in the research, carried out by Atheros, in closed office environment structures subscribers throughput even on the base of one access point (AP) may vary up to 10 times depending on its BER level [1]. Therefore, we must calculate the throughput for each wireless channel according to its BER level.

Thus, the development of appropriate models and methods for calculating BER level in 802.11 error-prone wireless channels is relevant.

State of the art. Analysis methods for BER study show that there are three approaches and appropriate models and methods for calculating BER level in a wireless channel [2].

The first approach uses analytical dependences for calculating BER level. In such calculations a distance between the subscribers, data rate and modulation method are taken into account [3]. However, analytical model cannot take into account many features of the environment where wireless network is located. Therefore, the results of throughput calculations, using this approach, can be far from actual values.

The second approach is based on experimental measurements of Signal to Noise Ratio (SNR) in receiver and BER calculation on a base of SNR value [4]. The disadvantage of this method is that the received signal power in a wireless channel is measured by the receiver only during reception of a physical layer preamble, the duration of which is about 3% of a frame transmission cycle. This can lead to large errors in BER calculation and hence to large errors in calculation of the throughput of wireless channels [2].

The third approach is based on experimental methods for direct measuring of BER level. To implement this approach it is necessary to use a specialized equipment (programmable signal generators and logic analyzers) and specialized software [2].

The cost of such equipment can be 10 times higher than the cost of wireless network, which measurements are conducted for. Thus, this approach is very expensive and time consuming, therefore it is practically not used in a real practice.

In the article an experimental based approach and appropriate model oriented method of BER calculation is offered. BER calculation is performed using mathematical model of wireless channel throughput. As a basic metric for BER level calculation experimentally measured throughput of wireless channel is used. The method allows with a high accuracy to calculate the average value of BER level for the whole transmission cycle.

Model oriented method. In the article a mathematical model of channel throughput for a Base transmission cycle (BTC), which is the most commonly applied in 802.11 wireless channels, is used [5]. The procedure of a frame transmission in this mode can be represented as a following sequence of time intervals and blocks of information: DIFS → Back of period → DF → SIFS → ACK, where DIFS, Back of period and SIFS – time intervals defined by standard, DF – data frame, ACK – acknowledgment frame [6].

Time of 802.11 Base transmission cycle we can write as

$$T_{\mathrm{BTC}} = T_{\mathrm{DIFS}} + T_{\mathrm{BOP}} + T_{\mathrm{DATA}} + T_{\mathrm{SIFS}} + T_{\mathrm{ACK}}, \quad (1)$$

where T_{DIFS}, T_{BOP}, T_{SIFS} – time of DIFS, Back of period and SIFS intervals, T_{DATA}, T_{ACK} – time of data and acknowledgment frames transitions.

Time of data frame transmission is defined in 802.11 standard as

$$T_{\mathrm{DATA}} = T_{\mathrm{Preamble}} + T_{\mathrm{PHeader}} + \lceil L_{\mathrm{MSDU}}/DR \rceil, \quad (2)$$

where T_{Preamble}, T_{PHeader} – time of frame preamble and header transmission, L_{MSDU} – length of data frame information field, DR – data rate, $\lceil\ \rceil$ – the next highest integer.

ACK frame transmission time is defined in 802.11 standard as

$$T_{\mathrm{ACK}} = T_{\mathrm{Preamble}} + T_{\mathrm{PHeader}} + \lceil L_{\mathrm{ACK}}/DR \rceil, \quad (3)$$

where L_{ACK} – length of acknowledgment frame.

Using the given above equations (1)–(3) we can calculate the time of Base transmission cycles for the IEEE 802.11g standard.

Using equations proposed in [7–9] we can calculate throughput of wireless channel for the Base transmission cycle with retransmission as

$$CT_{\mathrm{BTC}} = \frac{L_{\mathrm{MSDU}} \cdot (1 - P_{\mathrm{DP}})}{T_{\mathrm{DATA}} + T_{\mathrm{ACK}} + T_{\mathrm{PAUSE}}}, \quad (4)$$

where P_{DF} – probability of frame distortion in wireless channel, $T_{\mathrm{PAUSE}} = T_{\mathrm{DIFS}} + T_{\mathrm{BOP}} + T_{\mathrm{SIFS}}$.

This expression (4) is a mathematical model for calculating the throughput of the IEEE 802.11 standard wireless channel for the Base transmission cycle with retransmission.

The probability of frame distortion in wireless channel can be expressed as

$$P_{\mathrm{DF}} = 1 - (1 - BER)^{\mathrm{N}}, \quad (5)$$

where $N = L_{\mathrm{MSDU}} + L_{\mathrm{ACK}}$.

To simplify the procedure of BER calculation we will use P_{DF} approximation. Using binomial decomposition expression (5) it can be represented as a polynomial:

$$\begin{aligned} PDF &= N \cdot BER - [N(N-1)(BER)^2]/2 + \\ &+ [N(\mathrm{N}-1)(N-2)(BER)^3]/6 - \\ &- [N(N-1)(N-2)(N-3)(BER)^4]/24 \ldots + (BER)^N \end{aligned} \quad (6)$$

In this expression the members, starting from the second, are two orders smaller than the previous. So we can use the approximation to calculate *PDF*:

$$PDF = N \cdot BER. \quad (7)$$

Using (7) from equation (4) we can express BER value as:

$$BER = (1 - \frac{CT_{\mathrm{BTC}} \cdot T_{\mathrm{BTC}}}{L_{MSDU}}) \cdot N^{-1}. \quad (8)$$

Using the equation (8) we can calculate BER level in a wireless channel. As a parameter for BER calculation we will use experimentally measured wireless channel throughput CT_{BTC}.

Experiments description. For experimental throughput measurements we will use JPERF traffic generator, which has built-in tools for TCP and UDP packets generation and throughput measurement [10]. For traffic generation JPERF an agent-server scheme is used. We will conduct throughput measurements in 802.11g WLAN using a Closed Office structure with some obstacles between subscriber and access point (Fig. 1).

The experiments have been carried out at various points in the office for various distances between subscriber (Computer 1) and access point (AP). The measurements are carried out by the following scheme. For a maximum frame size of 1500 bytes channel throughput measurement is performed using a JPERF generator.

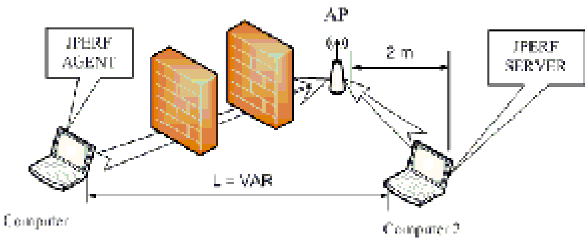

Fig. 1. Experimental scheme

By the equation (8) BER level in the channel is calculated. Then a frame size consistent reduction is performed. For each frame size the experimental measurement of channel throughput is conducted. Using equation (4) and BER value obtained in the first experiment analytical calculation of channel throughput value is performed. To assess the accuracy of the method for each frame size error values δ for analytically obtained channel throughput are calculated

$$\delta = \frac{CT^{C}_{BTC} - CT^{M}_{BTC}}{CT^{M}_{BTC}} \cdot 100\%,$$

where CT^{C}_{BTC} – calculated value of channel throughput, CT^{M}_{BTC} – measured value of channel throughput.

Experimental analysis of the method accuracy shows that the maximum error occurs at the point of maximum distance between subscriber and access point. For this point a graph of methods inaccuracy depending from the size of transmitted frames is shown at Fig. 2.

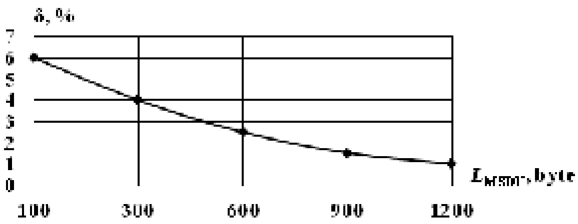

Fig. 2. Graph of method inaccuracy depending from the size of transmitted frames

The analysis of the graph shows that the maximum error does not exceed 6%, which indicates a high accuracy of proposed method.

Conclusions. Model oriented method of BER calculation is offered. BER calculation is performed using mathematical model of wireless channel throughput. As a basic metric for BER level calculation experimentally measured throughput of wireless channel is used. The method allows to calculate the average BER level for the whole transmission cycle. Experimental study of the method has shown that the maximum error of BER calculation does not exceed 6%.

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In the article analyses of approaches and appropriate methods for BER calculating in a wireless channel have been conducted. The first approach uses analytical dependences for calculating BER level. However, analytical model cannot take into account many features of the environment where wireless network is located that leads to a high inaccuracy of calculation. The second approach is based on experimental measurements of Signal to Noise Ratio (SNR) in receiver and BER calculation on the base of SNR value. The disadvantage of this method is that the received signal power in wireless channel is measured by receiver only during reception of physical layer preamble, a duration of which is about 3% of frame transmission cycle. The third approach is based on experimental methods for direct measuring of BER level. To implement this approach it is necessary to use specialized equipment and software. This approach is very expensive and time consuming, therefore it is practically not used in a real practice.

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The proposed method allows with high accuracy to calculate the average value of wireless channel BER level for the whole transmission cycle.

Keywords: *802.11 wireless networks, bit error rate calculation, model oriented method, traffic generator, wireless channel throughput.*

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